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TITLE: Carbon dioxide snow agglomeration and acceleration

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The agglomerated snowflakes exiting from outlet 21 of large expansion chamber 20 are introduced into acceleration chamber 22 to accelerate and further agglomerate the snowflakes. Outlet 21 is spaced from the entrance to acceleration chamber 22 of vortex nozzle 23 to allow clean, dry gas such as filtered nitrogen or air to be sucked into the vortex nozzle along with the carbon dioxide gas and snowflakes from outlet 21. The amount of spacing between insulation material 24 and vortex nozzle 23 should be sufficient to prevent obstruction of flow of the clean, dry, gas into the vortex nozzle 23 along with the carbon dioxide gas and snowflakes from outlet 21, but preferably less than about 5 cm. For example, excellent results may be obtained with a spacing of about 1 cm. If desired, the spacing between insulation material 24 and vortex nozzle 23 may be enclosed in a suitable housing such as a manifold (not shown) that supplies the clean, dry, gas into the vortex nozzle. Acceleration chamber 22 has a generally conical entrance, a constricted throat, and an exit which gradually increases in diameter. Compressed gas is introduced through feed line 42, valve 40, annular chamber 34, and ring nozzle 36 into acceleration chamber 22 at high velocity. The resulting primary high velocity gas stream from ring nozzle 36 adheres to the coanda profile and is

directed toward the outlet 44 of acceleration chamber 22. A low pressure area is created at outlet 44 of acceleration chamber 22. This low pressure region induces high volumes of a second gas to enter the space between outlet 21 exit of large expansion chamber 20 and the entrance of acceleration chamber 22 and combine with the stream of large snowflakes emerging from outlet 21. This secondary stream of a second gas and stream of large snowflakes combine with the primary stream of gas introduced into acceleration chamber 22 through the ring nozzle 36. The combined flow of the primary, secondary and snowflake streams exhaust from the outlet 44 of acceleration chamber 22 as a high volume, high velocity stream.

A carbon dioxide cleaning device identical to that described in Example I was coupled to a vortex nozzle and all the process conditions of Example I were repeated except that the large agglomerated snowflakes exiting from the open end of the large expansion chamber were not sent directly against the surface to be cleaned and the distance of the open end of the large expansion chamber to the surface being cleaned was slightly greater due to the presence of the vortex. More specifically, the large agglomerated snowflakes exiting from the open end of the large expansion chamber were introduced into the acceleration chamber of a vortex nozzle having a 1:14 amplification (Brauer AM 20, Model 6021, available from EXAIR Corporation). This vortex nozzle had a generally conical entrance, a constricted throat, and an exit which gradually increased in diameter. The open end of the large expansion chamber was positioned about 1 cm from the conical entrance of the vortex nozzle and held in place by a spider type centering device made of small diameter polished stainless steel

wire. Compressed nitrogen gas at a pressure of 3.5 Kg/sq cm was introduced through a valve into an annular chamber of the vortex nozzle and out through a ring nozzle into acceleration chamber of the nozzle at high velocity. The resulting primary high velocity gas stream from the ring nozzle adhered to the coanda profile and was directed toward the outlet of the acceleration chamber of the vortex nozzle. A low pressure region was created at the outlet of the acceleration chamber which induced high volumes of a secondary gas (air) to enter the space between the open end of the large expansion chamber and the entrance of the vortex nozzle, i.e. the entrance to the acceleration chamber, and combine with the stream of large snowflakes emerging from the open end of the large expansion chamber. This secondary stream of air and the stream of large snowflakes combined with the primary stream of fluid introduced into the acceleration chamber through the ring nozzle. The resulting combined flow of the primary, secondary and snowflake streams was emitted from the outlet of acceleration chamber of the nozzle as a high volume, high velocity stream. The amplification of the velocity of the stream of large snowflakes was greater than about 1:2. The large agglomerated snowflakes exiting from the open end of the vortex nozzle were directed against a flat metallized surface of a polyester film at an attack angle of about 20.degree.. The distance between the open end of the vortex nozzle and the metal surface (measured along the length of the snowflake stream) was maintained at about 7 cm. The effectiveness of cleaning was measured by seeding the surface of the metallized film prior to cleaning with a fluorescent powder having a particle size of between about 1 micrometer and about 30 micrometers. Analysis of cleaning

effectiveness was made by exposing the surface to long wave ultraviolet light to excite and render visible the fluorescent particles and examining the surface with a 100 power microscope. The area of effective cleaning (at least 99.8 percent of the seeded particles were removed) was improved from the 10 cm distance downstream from the center of the initial snowflake impact zone achieved in Example I to 30 cm downstream from the center of the initial snowflake impact zone.